Rust
Prevention

By

L. M. Stern

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RUST PREVENTION

A TREATISE

On the preservation of Structural Steel used in bridges, buildings, fire escapes, etc., and Sheet Steel used in buildings, metal siding, roofing, smokestacks, boiler fronts, and standpipes, etc.

FOR

Anyone having in charge their maintenance. Also property owners, architects engineers and metal workers, etc.

By L. M. STERN

INTRODUCTION.

The use of steel has increased so rapidly within the past ten years that the keen competition in cost of production between the manufacturers thereof, has caused an enormous amount of this metal (particularly in Sheet Steel and Terne Plates for exterior use) to be thrown upon the market, of a quality unsatisfactory to those who have to shoulder the responsibility of its proper maintenance.

Since the advent of the Bessemer process of making steel cheaply, the use of "charcoal iron" has comparatively decreased. Iron ore is very rarely reduced to pure metallic iron for commercial purposes, consequently the foreign substances which have not become eliminated from it constitutes part of the material entering into its transformation into steel.

The progress of disintegration of steel exposed to reactionary agencies largely depends upon the quality of the metal, nickel steel, for example, being but very slightly susceptible to corrosive action, while Bessemer process steel being the reverse.

The intention of this treatise is to deal briefly with the protection of the surface of the metal, so that corrosive action may be prevented from exterior sources, and in pursuing this course, we must of necessity carry on the discussion with the understanding that the steel or iron exposed to corrosion is of the quality which ordinarily comes from the mill, leaving the question of placing cheap and better steel upon the market for structural purposes to those who manufacture it.

There are a great many paint manufacturing concerns who make ridiculous and absurd statements in their advertising matter, in the claims which they make

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regarding wonderful properties possessed by a material which they offer for sale to prevent corrosion and rust on all kinds of metal work.

One large concern advertise that they are the sole manufacturers who own a mine yielding graphite of such a peculiar flake form that paint made with it possesses the wonderful properties of the flakes arranging themselves like the shingles on a roof or the scales on a fish, during the progress of painting a surface with it, claiming as a result thereof, that " the flakes so arranged would protect the oil in the interstices from evaporation or excessive oxidation." This manufacturer fails to state what form these scales would take if the painter would forget himself and use his brush in the usual manner, plying it back and forth on the surface so that the paint would draw from both sides of the brush.

The property owner should post himself sufficiently to be able to guard against deception and fraud. The painter cannot be depended upon for any definite knowledge of metal preservation. He either finds it unprofitable to waste his time thinking about the matter, or has no inclination to have his paint cost him more than what is absolutely necessary—hence his recommendations and advice are more often given than asked for.

Since the author's first treatise on this subject, published in 1901, extensive practical tests of various pigments and liquids for their protective durability have been under his close surveillance in various sections of the country, covering a wide range of climates. More truths have been revealed regarding the most suitable protective coating to resist the particular climate or exposure at hand, and it is to be hoped that this treatise will contribute enough light on this subject to induce the architect, engineer or property owner (either having charge of construction work or the maintenance of the work after completion) to be more cautious in the selection of the most suitable materials.

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The author desires it to be borne in mind that as his livelihood depends upon the sale of all kinds of materials for the prevention of rust, any influence or assistance that the reader can extend toward their purchase from him, will be duly appreciated, and that the same judgment, resolution and practical experience which prompted the issuance of this treatise will be devoted to the interest of those so inclined.

Theories and the chemistry of paints will herein, as far as practical, be avoided, and a strict adherence to practical knowledge maintained as faithfully as possible, so that the ordinary person, whether experienced or otherwise, requiring some good general pointers on the subject may find this treatise of some practical and financial benefit.

Very truly yours,

L. M. STERN,

571 EAST NINETY-NINTH STREET, CLEVELAND, OHIO.

RUST PREVENTION.

Chapter I.

Iron Rust and Its Formation.

Circumstantial evidence convinces us that iron at one time, say thousands of years ago, might easily have been or in fact was distributed over portions of the earth in a metallic state and that the subsequent action of oxygen, sulphur, silica and other elements have converted it into the state in which it is now found and which is commonly called iron ore.

Iron ore resembles rust in appearance and not only contains the two important elements of rust, of which it principally consists, namely (Fe_2O_3), but it contains other elements as well, such as sulphur, and silica, &c.; hence it remains for man to undo what nature's laboratory has done for centuries and separate the elements closely united in the composition of the ore and thus obtain the metallic iron for use in the arts.

Rust is a reddish brown deposit, generally noticed on the surface of steel and iron after having undergone deterioration by chemical change, due to exposure to agencies, causing its formation. It ordinarily consists mostly of oxide of iron, together with other minor substances and water.

The compound known as oxide of iron consists of the chemical combination of two parts of iron with three parts of oxygen, commonly expressed in chemistry by the symbol (Fe_2O_3) the first two letters representing the Latin term Ferris, meaning iron and the letter O representing the word oxygen.

For the reason that iron oxide is an hydroscopic salt, it has the property of absorbing water, intimately holding a portion of it in close affinity with its molecules; this, however, does not change its chemical composition to any appreciable extent, for the reason that the water does not form a chemical solution with the oxide. Thus, rust is termed a hydrated oxide of iron, which is symbolized in chemistry as $Fe_2O_3 + (H_2O)$, which is oxide of iron

plus water. This water is free to act on metallic iron into which it may come in contact, forming additional rust, thus creating more room for water absorption and continuing the process of rust formation indefinitely.

The chemical decomposition of the steel or iron by the combination of particles of the metal with oxygen is accelerated by frequent contact of the metal with oxygen in a condensed form, such as is found in liquids, and its subsequent evaporation in the presence of gaseous oxygen such as atmospheric oxygen, &c.

Thus a solution of oxygen in the form of rain, dew or other forms of moisture, when deposited on an iron surface and quickly evaporated, will rust the surface much more readily than if the water or moisture were maintained on the surface. In high and dry climates, where the proportion of pure oxygen is greater in the atmosphere, iron and steel will not rust as quickly as in low damp valleys, where fogs and heavy dews are prevalent, so that the conjoint action of atmospheric oxygen and water or other forms of moisture may act upon the surface.

A piece of steel can be seen to rust in a few moments time after the evaporation of water from the surface. All forms of iron, whether sheet iron, steel, pig iron, cast iron, malleable iron, or any condition of bare and unprotected iron or steel surface exposed to frequent renewals of moisture and atmospheric oxygen, become rusted, and the aggressiveness taken by this form of reagent depends not only on the frequency of evaporation and renewal of moisture, but on the cleanliness of the surface thus exposed and temperature of and active qualities of the water, coacting with the atmospheric oxygen as well, together with the chemical composition of the steel, some grades of steel being attacked far more readily than others.

The writer has seen steel girders on bridges so badly rusted that portions of them, when coming in contact with the pressure of the hand, would slough away like a rotten log. Some rusted sections would be directly below the coating of paint, which would be in an almost perfect condition on the surface. This rusted metal would be piled up in layers, one upon the other, completely affected through the entire thickness of the original beam, which upon examination would reveal the fact that the steel had been imperfectly rolled or refined during the

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process of manufacture, resulting in seams resembling an imperfect weld, which would accumulate rust and by the admission of moisture in the interstices and the contraction and expansion of the metal would loosen up the crevices between the layers so that they could be rent asunder with a pocket knife, like sheets of mica.

Steel kept under water, in the ground or set in cement, which will admit oxygen and moisture and allow the same to be evaporated, is eventually doomed to premature rust and decay.

All of the hydroscopic salts, especially common salt, magnesium chloride, potassium chloride, ammonium chloride aid and assist in forming rust.

Carbonic dioxide gas (CO_2) which is constantly being poured into the air from our chimneys and our lungs, sulphuretted hydrogen from coke ovens and furnaces, likewise attack the metal surface and assist in the formation of the compound which we call rust.

Water impregnated with caustic alkali will not rust steel readily, provided the steel be immersed in a bath of the same and be continually kept beneath the surface.

Almost all of the acids, when diluted with considerable water, rust iron and steel considerably, and strange as it may seem the fact nevertheless remains, that a great many acids attack steel more vigorously when diluted with water than otherwise. This fact may be due to the oxygen in the water co-operating with the acid in chemically decomposing the surface of the steel and converting the same into rust.

Steel once rusted is more readily attacked, and its decomposition takes place more readily than when in its original condition, unless the surface has been divested of all metallic oxidation prior to the renewal of the formation of this compound.

The tensile strength of rust cannot be relied upon for any practical purposes, and it is almost safe to say that the amount of steel surface attacked by corrosion has not only lost its equivalent amount of strength and is burdened by the weight of the rust, but the factor of safety is lowered to the basis of the weakest point formed by corrosion.

The formation of rust may be classed as arising from two different conditions, which we will assume for the purpose of argument are:

Primary Condition.—Those conditions where the sur-

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face has been exposed to ordinary rust generating influences, such as ordinary atmospheric conditions.

Secondary Condition.—Those conditions where the surface has been attacked either by substances attached to the surface or by the action of extraordinary atmospheric conditions. (Atmospheres impregnated with acid fumes, &c.)

Rust can be economically removed very readily by mechanical means, and this is the only means by which it can be done on a large scale successfully. Abrasion and hammering with a tool conveniently handled and applied to the surface is the method recommended by the author. Flat surfaces that will admit of the use of a steel wire brush should be gone over vigorously, both lengthwise and crosswise, so that all loose scales and irregular masses may become detached; then a hammer, file and cold chisel should be brought into use, as well as a painter's wall scraper or putty knife wherever there is an accumulation of any thick incrustation. After this treatment has been completely accomplished, the steel brush should again come into play, as before, after which a vigorous application of coarse emery cloth or sandpaper should be employed, in lieu of which steel wool or steel shavings may be substituted for the final removal of all loose and scaly formations of rust.

After the above treatment is completed in as thorough a manner as possible, a good heavy bristle brush should be used to dust out the finely powdered rust, and then the surface should be finally wiped off clean with a dry cloth. The hot blast from a painter's torch may sometimes be found to work to good advantage in evaporating as much moisture as possible out of the rust, which operation may result in reducing considerable of it into a powdered state.

The use of the sand blast produces the best results, but this is often too expensive a process.

Any vigorous treatment for the removal of rust may be recommended in so far that the treatment thus affected does not crack, break or otherwise injure the metal nor leave any condition liable to impair the means of protection afterwards to be employed.

A wet process, or the various applications of oils, such as benzine, gasoline, creosote oil has been recommended by many users of the same, and these may be used to advantage to penetrate deeply into rust incrustations

and thereby aid the hot blast from the painter's torch in evaporating moisture, as heretofore mentioned. The writer has not, however, found them to possess any special beneficial chemical properties in rendering rust inactive after the oil had evaporated therefrom. Oil once eliminated from rust leaves it in practically the same active condition as it would had it not been impregnated or covered with it.

The author has found one advantage, however, in soaking powdered rust with oils immediately prior to its removal, and this is that the rust is capable of adhering to a cloth when rubbed on the surface thus oiled, forming a sort of coagulated mass of rust paste, which may be used to great advantage in contributing friction or grinding properties, much after the fashion of the old style "bath bricks," which were used to clean and brighten rough table ware.

We have observed the reasons why rust forms, and we will henceforth turn our attention to the measures whereby the accumulation of rust may be prevented; in other words, the ways and means whereby steel and iron may be maintained or kept free from contact with oxygen and atmospheric moisture. The ways and means by which the same may be done is, of course, to cover the surface with a noncorrosive substance; something which will not contain nor transmit any oxydizing medium to the surface of the metal. It must, therefore, as far as possible (for all practical and economical reasons), possess the qualities of easy application, maximum amount of protecting durability and a minimum amount of cost.

Chapter II.

Some Chemical Elements and Their Symbols.

By chemical element we mean those substances which are not made up of two or more substances. They are not necessarily distinguished by any external appearances, but are known to science as substances which cannot be decomposed. We can convert them into thousands of other substances, but in all cases extra weight and material has been added, but none taken from an element composing a compound.

For illustration, we may decompose water by an electric current, first weighing the water. The hydrogen and oxygen that become separated we know were in combination, and the weight of both together equal the weight of the water, for on combining them again we may thus prove that water consists wholly of hydrogen and oxygen.

A nice illustration of the combining of two elements may be shown by the burning of finely pulverized metallic iron in the presence of oxygen. The result of a change is a substance which we call oxide of iron. This substance obtained has increased in weight, proving that material has been added to it, and not taken from it, the extra weight being due to its combination with oxygen.

This experiment illustrates a most remarkable truth in regard to the substance we call iron. By various chemical processes we can produce from the metal hundreds of different substances, but, in all cases, the condition of the experiment and the relative weight of the products prove that material has been added to the iron and not taken from it.

By no chemical process whatever can be obtain from iron a substance weighing less than the metal used in its production. In a word, we can extract nothing from iron but iron; in like manner we cannot extract anything from carbon but carbon, nor, in fact, any material from any element but part of the element itself.

In chemistry the initial letters of the Latin names of elementary substances are represented to denote one atom of each element. These are called chemical sym-

bols. The symbols of these elements, which sometimes enter into the composition of paints, oils or varnishes, or compounds entering into the destruction of the same while under exposure, are as follows:

Aluminum ....Al.	Manganese ....Mn.
Barium ....Ba.	Mercury ....Hg.
Calcium ....Ca.	Nitrogen ....N.
Carbon ....C.	Oxygen ....O.
Chlorine ....Cl.	Potassium ....K.
Copper ..:.............Cu.	Silicon ....Si.
Hydrogen ....H.	Sodium ....Na.
Iron ....Fe.	Sulphur ....S.
Lead ....Pb.	Zinc ....Zn.
Magnesium ....Mg.	

The full list of elements are set forth in almost any work on chemistry. Those not here mentioned are omitted for the reason that they are rarely, if ever, met with within the scope of the subject here at hand and would only have a tendency to burden the reader with unnecessary and uninteresting complications.

Chapter III.

Rust Prevention.

Since we have noticed that the exidation, rusting or corrosion of iron is due to its chemical combination with substances with which it has uniting properties, and that the resultant product is what we call rust, primarily consisting of $Fe_2O_3 + (H_2O)$, we necessarily conclude that we can only prevent the formation of this compound on the surface of the metal by maintaining its isolation from substances necessary for its propagation, thus reaching the foundation of its protection.

There are many ways and means of accomplishing this, and innumerable substances may be used for applying on the surface of the metal, all of which have widely different characteristics, and also great variation of permanency or efficiency; but we are interested chiefly in the most economical and reliable method of doing so.

We know that water (H_2O) and atmospheric oxygen alternately acting on the metal surface are the most prevalent rust generating mediums, causing rust, and therefore should expect to obtain materials for application on the surface of the metal that are not easily affected by these agents, or the mediums which cause the secondary condition to produce rust.

The efficiency of protective coatings for metal surfaces are entirely dependent upon the character of exposures, adhesiveness of the coatings, resistance to abrasion, and other qualifications, in consequence of which we are led to investigate the various conditions in order to meet them in the most economical and convenient manner possible.

Oils and greases of various kinds have been used for protecting metallic surfaces from the absorption of oxygen. Great varieties of them are used where the exposure is not permanent or severe, and the oils or greases are to be removed easily after they have served their purpose; for example, machinery, firearms, carpenters' and mechanics' tools, &c., and even these, if left out in the rain, will become rusted soon after atmospheric conditions or water obtains the mastery over the coat-

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evaporation or decomposition. The question, however, of ing, causing its washing off by friction or elimination by temporary prevention of rust by the use of oils and greases is of small importance compared to the protection of costly steel and iron structures and other large metal surfaces, and consequently these will engage our attention so that the selection of the proper materials for the production of protective coatings may be accomplished in the manner most desired.

Various paints, oils and varnishes may be used. and their protective qualities will last as long as they will be devoid of water absorbing properties, and maintain a coherent adhesive coating on the surface.

The author has ascertained by actual tests that there exists a wonderful variation in the aggressiveness of various pigments coacting with atmospheric moisture in attacking a metal surface, when the oil has dried out, leaving the paint porous enough to absorb moisture. It will then be seen that a destructive agent finally ensues from the material which was originally intended for a protective addition to the oil.

Very often an oxide paint pigment is mixed with oil and used as a protective coating for metal. The oil neutralizes temporarily the oxidizing properties of the pigment in question, but when the dried paint becomes porous by the disintregation, excess oxidation, or evaporation of the oil, the oxide pigment takes up moisture, carries it to the metal surface and there conducts a process of conjoint attack in generating rust that would not be possible with a carbon pigment used under similar conditions.

Porosity of a paint can often be detected by the appearance of stains from moisture with which the paint becomes saturated, and by cutting into the moistened paint with a pocket knife a fair idea may be had as to whether a fresh application of paint is necessary to prevent moisture from gaining admission through the coating and coming into direct contact with the metallic surface.

The porosity of a paint, however, is very rarely taken notice of in time to prevent rust, as it often, while in this condition, appears to remain a coherent, adhesive mass of fair density and resistance to mechanical abrasion. The most noticeable feature which may be easily discerned in this respect, however, is that the coating

has lost its glossy appearance, and appears dead or dried out, and even in this condition it is not always porous enough to admit moisture entirely through the coating.

The illustration shows what can be done in the laboratory to definitely ascertain the amount of porosity of any kind of paint or varnish. Owing to a chemical phenomenon, any dried coating of paint having been exposed to the weather any number of years may be by the author easily removed from the metal surface intact and without injury. The paint thus removed can be accurately tested for porosity, elasticity and adhesiveness.

Plate I.

and the thickness of it may be tested at different points with a micrometer or depth gauge.

A simpler and more satisfactory way of testing or ascertaining porosity of a paint film for the ordinary person, however, would be to apply the paint on sheets of glass, expose the same to the weather for from one to five years at a convenient place, so that the sample may be taken down and held up to the light at different stages of exposure, and thus any ordinary amount of porosity can be very readily seen.

Paints or varnishes intended chiefly for decorative

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purposes, that will last for 15 years on the inside wood-work of a residence, will do well if they last more than five years on the outside woodwork of the same residence, and would be an exception, indeed, if they would last over two years on the tin roof or gutters, thus demonstrating the great difference in exposure and consequent variation in the decomposition of the paint on different portions of a house.

It remains for us, therefore, to compound paints for specific purposes, made of such material that will give them the greatest efficiency. Knowing why, where and when the different materials necessary for their composition may be used to the best advantage, not, however, taking for example the various materials used to preserve or beautify wood, for while one class of paint may be suitable to both wood and metal, this condition would merely be an incident when atmospheric or other severe exposures would prevail.

In a majority of instances paint dealers throughout the country sell most of the paint intended for wood surfaces from $1.25 to $1.50 per gallon. Yet, when it comes to paint for metal roofs, the prevailing condition seems to be that the dealer canot sell a paint for this class of work for more than 50 or 75 cents per gallon. Why? Because the uninformed possessors of false economical paint principles believe " If the paint on the visible exterior of the house, which is expected to look pleasing to the eye, cost a certain price, paint that is put up on the roof and which is not necessary to look pleasing to the eye, should not cost half that price." Therefore, the price that controls the quality of paint on the market for metal roofs which are sold by the dealer are, unfortunately, kept down by popular demand.

Another reason for a vast amount of cheap trash on the market for metal protection and called paint is the fact that the painter or tinner applies a cheap quality so that his own temporary profits may be thus gained. Painters and tinners invariably are asked by their customers for prices " per square " for doing the job (details of quality and materials omitted), and in order to secure the work he is tempted to make a price consistent with his chances of a successful issue. As a rule the tinner does not care much whether the paint he puts on wears one or five years. It makes no material difference to him. It may present a good appearance for a few

months after it is applied, and be almost entirely washed off in a year or so afterward.

There are many paints that will wear well for a period of from 5 to 10 years on sheet metal exposed to the weather, and also on bridges, but the manufacturers of these are compelled very often to give a very close bid in order to get a contract and are compelled to use cheap material; in fact, they have often made the statement to those who attempt to sell them high grade paint that "our customers will not pay us any more for our material with high grade paint than if it were coated with the cheapest that could be obtained."

Chapter IV.

Paint Ingredients, their Classifications and Functions.

Paint ingredients we shall divide into two general classes, namely: Liquids and Solids. They consist of the following:

1. Pigments—(dry powdered, insoluble substances).

2. Vehicles—(Liquid materials for carrying the pigments).

3. Volatile oils and dryers—(Evaporating oils, &c.).

4. Soluble Solids—(Solid substances for dissolving into the liquids.

Pigments (for paints) are those dry powdered substances intended for mixing with liquids for the purpose of making liquid or paste paints.

All pigments when dry hold water freely.

The pigments used in metal preserving paints are all derivatives of minerals, on account of their cheapness in price, stability and durability, while those pigments which are made of vegetable and animal products are used for artistic and beautifying purposes.

Pigments are generally termed "dry colors," but this term is erroneous, for the reason that many pigments do not possess any color, being merely white or black. They are likewise termed "dry paints" which term is ambiguous, for the reason that dry paint is often the substance which results in a liquid paint becoming dry on a surface.

The definition of the word pigment, as above stated, in order to avoid confusion, should be well kept in mind. Pigments we separate into two classes:—Natural pigments and chemically produced pigments.

Those which are used in the manufacture of protective coatings are, as follows:

Black pigments.	White pigments.	Yellow, red and brown
Graphite, C....	White lead, $2PbCO_3$, PbH_2O_2.	Yellow ochre, Fe_2HO_6
Lamp black, C..	Oxide of zinc, ZnO....	Umber, $Fe_2HO_6+MnHO_4$
	Zinc white, ZnO......	Iron oxide, Fe_2O_3.
	Lead sulphate, $PbSO_4$.	Venetian red, Fe_2O_3+ impurities.
	Whiting, $CaCO_3$.......	Red oxide, Fe_2O_3+ impurities.
	Barytes, $BaSO_4$......	Red lead, Pb_3O_4.
	Barium sulphate, $BaSO$	Metallic red, Fe_2O_2+ impurities.

While there are many more pigments used than these mentioned for metal preserving paints, the balance of them are generally used for their coloring properties, or as a means of deceiving purchasers by false statements, as to extraordinary merits, which they are presumed to possess.

The function of a pigment is to thicken the vehicle, to make it opaque with a suitable material or color, to give the paint a viscid body (viscosity) and add toughness and durability to the paints when dry. Some pigments accomplish this with a great variety of results, especially when more or less of it is used than the amount necessary to perform its maximum amount of usefulness. The exact amount of pigment or pigments to be used in making a paint to possess the proper thickness when spread on a surface to obtain the greatest efficiency in its protection can only be ascertained by actual tests for their proper working qualities under the brush, and also withstanding the kind of exposure met with.

Actual tests for the durability of the pigment are necessary in determining the quantity of the pigment to be used for the reason that there is such a variety of grades of pigments on the market, and they posses an individuality of certain capacity for absorbing or " taking to " the oils used; that no set rule can be laid down for the actual amount to be used necessary to accomplish the best results.

This is especially true for the reason that one manufacturer's pigment is at variance in texture, freedom from impurities and other qualifications, from another's which bear the same name.

Each class of pigments has a different effect upon the drying or oxidizing properties of linseed oil: Some of these pigments retard the drying properties while others hasten the oxidation to a remarkable degree.

Among those of the latter may be mentioned all of the pigments containing oxygen in their composition. Red Lead (Pb_3O_4) especially. The pigments which contain oxygen prevent the formation of rust, while they are in combination with oils, but when the oils either evaporate or become excessively oxidized so that the pigments protrude through the film of oil on the dried painted surface, or in fact loses so much of the oil through exposure that the paint has become porous, it

then co-acts with moisture and atmospheric oxygen and the metal surface beneath the paint becomes rapidly and vigorously attacked, whereupon the very pigment which was originally a protective medium becomes a rust producer.

The carbon pigments are elements and consequently can only consist of carbon excepting where there is an impurity or an adulteration present and this is not as a rule premeditated, but rather accidental, at all events they are not generally found to any such a degree as they are in the lead or chemically produced pigments and even when not so the impurities in the former are invariably inert substances and do not promote chemical activity in producing rust.

The carbon pigments show a far superior resistance to the accumulation of rust, when the oils begin to wear out or become eliminated from a painted surface after prolonged exposure than do the oxygen pigments, moreover they are not affected to any extent by acids whether in the liquid or gaseous form. Hence, it will be seen that the carbon pigments are to be preferred, graphite especially, for graphite which is also used as a lubricant possesses such a degree of fineness of texture that it gives the paint where it is used as a pigment, such a slippery surface when several years dry, that it reduces to the minimum the abrasive effect of water, snow, ice or mechanical abrasion, etc.

We may easily destroy the efficiency of the best pigment by the use of admixtures whereby the pigment or the oil become impaired. A course granular substance added to graphite tends to give to the painted surface a rougher coating of paint which serves as a lodging place for water, which adheres by capillary attraction to the roughened surface.

Pigments as powdered dry substances are fixed or stable bases, but as coloring materials (excepting the carbons) they invariably fade after prolonged exposure, and while their stability as a base may be relied upon, the various effects which the different pigments possess in their co-active properties with drying oils is more or less important. It is not so important however, as the proper treatment of the oils to be used.

The most undesirable pigment mixed with the most desirable liquid material would make a fairly good paint compared to reverse conditions. The complex functions,

careful preparation of, and extreme sensitiveness of the liquids, necessitate a knowledge covering a much wider field of experience.

Moreover, pigments have less latitude in their functions and present opportunities of physical examination for requirements that are easily and finally determined.

Neither heat nor cold affects pigments to any undesirable extent,—graphite, Venetian red, red oxide, yellow ochre, umber and many others being fire-proof to the extent of readily withstanding temperatures, many times higher than that necessary to produce a red heat on steel. They are also acid proof to the extent of not being affected by the most effective acid fumes or gases that are possible in open atmospheres.

Many deceptions on this point are practiced upon the public by dishonest manufacturers, who claim or infer originality in that they have a fire and acid proof pigment, when in fact the majority of the most frequently used and cheapest materials for this purpose possess these features.

Deceptions are practiced to such an extent with graphite that many interested persons looking forward to the purchase of paint containing graphite as a pigment ask the question, "Where do you get your graphite?"

This deception arises from the fact of various manufacturers, convincing prospective purchasers that they own or control graphite mines which produce graphite of incomparable purity, or peculiar qualities not possible with any other.

It will be seen that the question of selecting pigments that will withstand heat, cold, and acids is a simple one, and that the white and colored pigments contain oxygen which when combined with a drying oil hasten more or less the oxidation of it, and that no risk whatever may be run in the selection of inert pigments, such as graphite or lampblack in the choice of the best and most protective mediums to be mixed with oil for the production of the most effective protective coating for metal surfaces.

The liquids used in paints are compound substances. They are not fixed or stable, and they constitute vehicles susceptible to decomposition, vitally affecting the durability of the film of a protective coating and therein lies room for constant investigation and improvement.

Vehicles are those liquids which are used with pigments to carry them in a fluid form for convenient application on the surface for which it is intended.

The functions which vehicles should perform in protective coatings for metal should be that they should have a close affinity with the pigments with which they are mixed and form a dry, waterproof and durable nonporous coating, one that will not chemically deteriorate the metallic surface on which it is applied. Certain oils have been found to possess the greater amount of these functions and those oils which dry on a surface by coagulation due to oxidation are being used for the purpose.

The oils which dry or coagulate by oxidation are not numerous, but their extraction, purification and subsequent treatment are very important, demanding a large amount of technical skill: these oils are more or less viscous varying considerably with the process and care taken in their preparation.

The value of an oil for use as a vehicle depends almost entirely upon its durability when dry: thus oils may be divided into two classes, the fatty oils, and the volatile oils, or evaporating oils.

The fatty oils are greasy and are incompatible with water; when oil and water come together they do not mix, (excepting when mixed with strong acids or alkalies) water running over a fatty substance does not wet its surface. This property is therefore useful for oil paints, for surfaces coated with an oil paint made of fatty oil and pigment are protected from the destructive action of water.

Those fatty oils which when exposed to the atmosphere, after being spread on a surface, become solid and coagulate into a varnish like coating, are known as drying oils and are distinguishable from the non-drying oils in that the latter remains either fluid or greasy for an indefinite period.

Among the drying oils the best known and most commonly used are linseed oil, poppy oil and Chinese wood oil. Poppy oil and Chinese wood oil, however, are not only too expensive to use for the manufacture of protective paints, but they do not possess sufficient durability over linseed oil to warrant the excess cost necessary for their use. All other drying oils either

dry so slowly or imperfectly that they are undesirable compared to linseed oil.

The drying power of oils is directly proportional to the amount of oxygen they are capable of absorbing, and if the absortion of oxygen is not checked the oil becomes over oxidized and loses its tenacity and cohesiveness.

The increase of drying properties of linseed oil is accomplished by extracting impurities which chiefly consist of cellular tissue and albuminous matter, etc. It is usually done by storing the oil in large tanks allowing the impurities to settle to the bottom after which the oil is drawn off, leaving the sediment behind. The oil is then clarified by passing through a filter press.

To further increase the drying properties of linseed oil it is boiled in the presence of manganese dioxide, manganese borate, red lead, litharge or other substances and raised to a temperature high enough and maintained long enough to impart the proper requirements to it. The treatment of linseed oil requires such a great amount of skill and experience, and the various forms of treating the same are so many that the study of it for a lifetime would develop new experiences continuously. Therefore, the treatment of linseed oil will not be discussed at length here.

When linseed oil dries it is called "Linoxyn" (Linseed oil + Oxygen) for the reason that it forms a perfect chemical union with oxygen and is then converted into the solid material thus named.

Linseed oil expands during the period of absorbing oxygen until it becomes thoroughly dry, after which the swelling up very gradually subsides. The expansion takes place to such a great extent that it is not only readily perceptable by appearance, but a difference in weight can be easily ascertained owing to the very large proportion of oxygen consumed in the process.

Almost any one familiar with linseed oil knows that after the drippings from a linseed oil can falls onto a piece of glass or other non-porous surface, it begins to thicken as it dries.

The formation of a paint or oil skin on the top of liquid linseed oil paint exposed to the atmosphere is thus easily accounted for as being a formation of linoxyn. It will be noticed furthermore that a linseed oil paint skin becomes crinkled on the top, and this is due to the absorption of more oxygen on the surface where contact

is had with atmospheric oxygen, than can be admitted farther below the surface thereby causing expansion on the top greater than the wet side of the skin which lies underneath. Gradually the paint skin admits more oxygen until the linoxyn gets thick enough to retard the progress of absorption, and reaches a point where it seems to cease.

It will be seen that pigments mixed with linseed oil cut down the percentage of linseed oil in proportion to its bulk, for the formation of linoxyn, and the subsequent clogging of the pores in the linoxyn by the pigment (which, if graphite, does it to a greater degree than the coarser pigments) renders the linoxyn for a limited time less porous than if the oil were not combined with the pigment; provided, however, that not more pigment be used than the oil will properly envelop and carry with it.

It will be noticed, moreover, that a fresh dried linseed oil paint film (without a volatile oil admixture) is thicker than when the coating was in the wet state. This causes the oil to expand and protrude above the pigment, thus exposing the protruding oil to direct attack of disintegrating influences, while protecting the pigment at the same time. Shortly after the linseed oil becomes dry and reaches its fullest extent of expansion it begins to subside and to lose its gloss, on account of becoming porous, and also for the fact that it becomes excessively oxidized and worn down to the pigment; at this stage oxidation and disintegration of the vehicle is retarded or accelerated according to the nature of the pigment, which if carbon accomplishes the former, and if oxygen pigments the latter. Hence, it will be seen that the organic matter of a paint which is the vehicle, is the unstable and highly sensitive portion of it that requires the most important and careful treatment.

The volatile oils used in paints are those generally called terpenes in chemistry. They usually belong to one of the groups of hydrocarbons having the same or a similar composition as turpentine ($C_{10}H_{16}$), they are highly inflammable and when dropped upon a sheet of glass and exposed to the atmosphere for a short time completely evaporate. The function of a volatile oil in paint is either to adulterate the linseed oil, lessen the viscosity of the paint, cause the paint to flow more freely so that a thin and consequently quick drying paint will

ensue, or for the purpose of dissolving gum resins so as to make a quick drying varnish, sometimes used as, (and erroneously called) a dryer. In this case the volatile oil evaporates from the resin leaving a thin coating or deposit of the resin of the same character practically as it was before being dissolved into the volatile oil.

The volatile oils usually employed are benzine, petroleum naphtha, coal tar naphtha (sometimes called creosote oil), benzole and turpentine. When these are used to any extent in linseed oil, paint not having a solid composition in solution with the oil, the paint loses considerable of its value. The pigment will separate from the oil freely and precipitate to the bottom soon after being mixed with the oil, the viscosity and adhesiveness of the paint would be impaired, the coating would be too thin to give ample protection and porosity would result immediately after the evaporation of the volatile oil from the painted surface, thus defeating the very object of a protective coating and rendering the coagulated mass of dried paint less efficient and durable.

Metal surfaces defy the absorption of paint to such a degree that the admixture of a thin or volatile oil for the purpose of creating a penetrating paint is useless. Hence, the lack of necessity of using a thin priming coat, which, if used, would run down in streaks on a vertical or inclined surface.

On the other hand, should the paint be made quite thick by the use of the pigment it will be done at the expense of the vehicle and its adhesiveness, as there will not be sufficient vehicle to carry the pigment over the surface to be painted, and leave a glossy oily finish.

Protective coatings for metal should be heavy bodied by the use of a heavy bodied vehicle and should be sticky enough in the liquid state to take to the metal freely from the brush. It should be capable of being brushed out thin or flowed on thick before it has time to set and should not run on a vertical surface when thus applied.

It should be quick setting but slow drying; the former to withstand unexpected rain storms shortly after application, and the latter to prevent premature hardening to a state of brittleness, not consistant with sufficient expansion and contraction of the metallic surface due to extreme changes of temperature, which on a dry paint film averaging one two hundredth of an inch in thickness, would not be inconsiderable.

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Soluble solids, as their name implies, are those solid materials which, when melted into a liquid state, are capable of being dissolved into the oils for the purpose of creating a compound vehicle or a varnish.

Varnish gums are soluble solids and so are tars, pitches, asphaltums and also prepared compositions made for the purpose; all of which have various and diverse qualifications for use in paints and varnishes for specific purposes, and a knowledge of their characteristics are necessary in order to select the proper ones for their adequate use.

The functions of soluble solids, in protective linseed oil paints, are to impart to the oil quick setting, adhesive elastic properties, viscosity and durability by way of protecting the linoxyn from over oxidation, and that state which is commonly called the " chalking off " condition of the pigment in the dry paint in which state it reaches the point where it has ceased to be a protective coating. The prolongation of the protective qualities of an oil by the use of a soluble solid depends entirely upon the character of exposure, together with the proper amount of, and character of, the soluble solid to be used in the oil, and also the quality of the oil to be used. The boiling down of linseed oil to a thick sticky consistency does not take the place of the proper sort of soluble solid, for the reason that it will not " take to " a sufficient quantity of pigment, neither will it allow of the production of free and easy spreading qualities. Furthermore, the oil thus treated does not delay excess oxidation, which is the feature most desired.

The progress of oxidation of linseed oil paints, not having a soluble solid, may easily be noticed after frequent rain-storms, dews or other forms of moisture have become evaporated soon after contact with the dried paint (similar to the action necessary to rapidly produce rust.)

The paint loses its gloss, becomes dried out eventually; so that the only perceptible part of the paint which is left is the pigment. All of these characteristics develop to a degree, proportionate to the frequency with which the applications of moisture on the surface and its complete evaporation therefrom has been accomplished.

A soluble solid to counteract these defects should be insoluble in water, but soluble in linseed oil, it should be solid yet elastic in its basic state and maintain this

condition without perceptible change; withstanding as large a variation of temperature as possible, it should not absorb oxygen nor become perceptibly effected by it, and when dissolved into the oil should form a compound vehicle which will effectively combat the attack of water, heat, cold, oxygen, sulphurated hydrogen gas, carbon-dioxide gas, and to a great extent the effects of the oxide pigments when the same, of necessity, have to be used. It should not impair the proper drying qualifications of the oil; that is not allow the coating to remain tacky or sticky for a long time after it is applied, and when necessity requires it, it should allow of sufficient volatile oil in combination to allow the paint to spread freely and set tough enough in a few hours to withstand the deleterious effect of unexpected rainfalls, and possess an amount of cohesiveness that the viscous mass of solid soluble material will flow together while the evaporation of the volatile oil takes place, leaving the surface tough, elastic, smooth and waterproof, thus eliminating the defects possessed by all of the straight oil paints where volatile oils are used.

The proper use of a soluble solid in linseed oil paints intended to prolong the life of a protective coating for metal has heretofore been but very feebly attempted by paint manufacturers. Rosin and some of the black pitches are often used, and these are used mostly as adulterants, or to add a temporary glossy appearance at the expense of the durability of the paint which contains it.

There has been little or no demand for the use of soluble solids in the composition of oil paints for the reason that the public has not known the benefits to be derived from the use of it. The extra cost necessary for its addition to paint, together with the difficulty of obtaining one possessing the requisite physical and chemical requirements which can only be ascertained after exhaustive and tedious tests covering years of experimenting, have induced manufacturers of protective coatings to abandon this feature in the composition of their products, and as a result almost all of the protective coatings now on the market with any claims to being high grade are straight oil paints with the omission of a soluble solid in their composition.

Those paints which are not of recognized standard as

being high grade often have rosin, pitch or a cheap rosin dryer in their composition.

The writer has been confronted with these facts for many years, and after an exhaustive system of experiments has succeeded in converting by a chemical phenomena in the use of chlorine gas, an oil of vegetable origin which has no drying or oxidizing properties, into a solid rubber-like mass of a light yellow color, completely converting the vegetable grease or fatty matter into a new substance, which, when melted (necessitating a heat of 600 degrees F.) turns black, flows like oil and is perfectly soluble in boiling linseed oil, becoming part of the vehicle itself and incapable of mechanical separation therefrom.

This soluble solid composition has in the past five years proven to be the missing link needed to produce a protective coating of the highest efficiency in every respect, and it is with pleasure to the writer that a protective coating with over twice the durability of anything yet produced for a top coat, of the highest efficiency is now produced and offered to those who are interested enough in this subject to demand it for their use.

The writer has become acquainted with paints that were represented to contain rubber (caoutchouc) and has personally made paints with this material. Manufacturers of so called "rubber paints" claim that the rubber contained in their paints make the paints more adhesive and elastic, thereby extending the life of the paint, by reason of its lessened liability to become hard and brittle and eventually crack.

The extreme high price of rubber, notwithstanding the small amount needed on account of its property of swelling up considerably in the oils into which it may become dissolved, makes its use in paint prohibitory, furthermore as a paint material it is worthless.

The author, as well as all manufacturers of rubber goods, know that oxidizing oils, or oils used in the manufacture of paint, will rot the rubber shortly after exposure to the weather, and when it has become dry on a surface its shrinkage opens up large crevices and the balance of it becomes crumbly, resembling a condition of dry rot. These circumstances clearly demonstrate that rubber has absolutely no value in paint and that the use of it in this respect not only entails a useless expenditure of money incidental to its cost, but also the cost of

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applying a paint containing materials which tend to curtail its efficiency.

In all cases investigated, however, the manufacturers' claim to using rubber, either new or old, in paint has proven to be a deception in order to obtain a high price for a coal tar product, or one no more costly in its production than one of this sort.

We have noted in the foregoing pages the functions of pigments, vehicles and volatile oils, and it will be observed that their action, while in combination as a protective coating, is more or less definitely understood. Not so, however, with suitable soluble solids, for as stated, none but deleterious hard brittle rosins, tars or pitches (or if they are not hard and brittle to start with they soon get that way under exposure) have been used and the author has no hesitancy in saying that he who solves the problem of intelligently compounding a soluble solid composition that will definitely double the life of linseed oil as a vehicle in protective coatings without increasing its cost, unlocks some of the secrets of chemistry, which, without doubt, is an acquisition of no slight value.

Chapter V.

VARNISHES.

Their Bases and Characteristics.

The line of demarkation as to what constitutes a varnish for a paint has been more or less confused where the varnish is not transparent and where the paint has a varnish vehicle. In order to avoid confusion we shall define a varnish as a liquid substance, not containing a pigment, which is capable of drying on a surface over which it has been diffused to beautify or protect the same.

A varnish may consist of a drying oil, a drying oil with a soluble solid base, or a volatile oil with a soluble solid base or the combination of any or all of these into one.

The drying oils we have mentioned on page 23, some of the soluble solid bases for varnishes are those mentioned on page 27, and the volatile oils used are those mentioned on page 26.

Varnishes may be either transparent or opaque, and, when the latter, they are generally black, such as tar varnish or asphaltum varnish, &c. The transparent varnish bases consist of common rosin, which is the residue left in the stills after the distillation of turpentine, or resins, originating by their exudation from various species of trees, some of which have disappeared centuries ago, leaving the resins embedded in the soil, and include mastic dammar, Sandarac, copal, kauri, and many others, all of which contain carbon, hydrogen and oxygen, and are very brittle at ordinary atmospheric temperatures and melt at temperatures ranging from 200 to 500 degrees F.

When they are combined with linseed oil or linseed oil paints they impart considerable viscosity and adhesiveness to the paint while in the liquid state, and when the paint becomes dry higher gloss and better finish, but after prolonged exposure to the atmosphere on a large metal surface subjected to considerable heat from the sun's rays, where rapid radiation of the heat and sudden cooling off of the metal causes considerable contraction

and expansion to take place; the paint rapidly becomes badly cracked and loses its adhesiveness.

The increased viscosity and adhesiveness of the liquid paint is not only lost in the dried paint, but it rapidly becomes very hard and brittle. This brittleness is due to the evaporation of the volatile matter in the paint or the excess oxidation of linseed oil in which a brittle soluble substance has very little lasting effect.

Pigments in combination with a resin or pitch tend to excessively harden them when they have become dry, and thus it will be seen that the separation of a pigment from a resin or pitch varnish is an advantage where great variations of temperatures are to be met with.

The pitches which are used in many of the so-called protective coating are coal tar pitch, asphaltum pitch and petroleum pitch, &c., and these go under so many different names, in order to hide their indentity from purchasers that it would be impossible to keep track of the new names, which are invented to deceive the unwary.

These pitches have to be made into very hard brittle substances by cooking them in kettles before adding the oils, otherwise their foundation as a base would not be solid enough to allow the substance to harden on a surface and become dry.

When pigments are added to a soft pitch with a view to causing them to dry it not only augments the lack of toughness, but serves to detract the stickiness from the pitch, for the reason that pigment alone has no viscosity, being a dry substance. Therefore when pitches are to be used they should be used in varnishes only, if they are to impart their full value to a coating intended for protective purposes.

The melting point of a pitch or resin is the degree of temperature necessary to maintain it in a molten state, and the brittle point is the degree of temperature necessary to cause it to harden into a brittle state, which state can be noted by striking it with a hammer.

Almost all of the different pitches have a different melting point, and one that softens while in combination with paint materials during exposure to atmospheric temperatures, and will correspondingly harden to a state of brittleness when the temperature lowers is sure to crawl and crack on the surface. These cracks form in transverse directions, forming a defective surface, which is known as being "alligatored," resembling in shape the

peculiar formations on the surface of an alligator skin.

When an "alligatored" surface forms and continued contraction and expansion of the metal ensues the edges of the alligatored scales will finally curl up, "letting go" of the metal entirely, thus allowing moisture and dust to get underneath them, facilitating the process of ridding the surface of the paint and promoting active rust formations.

The melting point of a pitch or resin may easily be ascertained by placing the same in a small iron cup, into which the bulb of a thermometer has been inserted, and noting the results after heat has been applied to the bottom of the cup.

Most of us know, however, that atmospheric heat on a warm day will soften coal tar pitch to such an extent that it will run on a surface or may be pulled out into long strings and after cooling it by dipping it into a basin of cold water it will fly into small pieces or may be finely pulverized by a simple blow from a hammer. This once soft and afterward brittle condition will be noticed where paints or varnishes containing these pitches are exposed on a surface at atmospheric temperatures, provided, however, that the same has been applied on the surface heavy enough to obtain from them their maximum amount of wear.

In proportion to its bulk it requires a large amount of volatile oil to reduce a resin, tar or pitch to a liquid condition thin enough to be capable of proper spreading properties, with a paint brush, at a temperature of 60 degrees F. Hence a very thin deposit of the solid base of the mixture will be left upon the surface after the volatile oil has evaporated. If extreme care is not taken in brushing it on thick enough to allow for the evaporation of the volatile oil and leave a substantial coating, lack of durability will be inevitable, for the coating which will remain on the surface will be so thin or badly disintegrated by the solvent action of the oil first, and its evaporation afterwards, that its adhesion to the surface will be a matter of only a few months, or even weeks, when subjected to atmospheric exposure, and soon afterwards no trace of it is liable to be seen whatever. On the other hand, should it be spread on too thick, a badly alligatored surface will result. These are the reasons why tar and asphaltum varnishes are so unreliable on tin roofs, and the author knows of no way

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in which they may be made reliable in a practicable way so that any one who knows how to spread paint can have some sort of definite assurance that it is going to last two years at least. For, as explained, the thickness of the coating has considerable to do with it, and as the volatile oil evaporates so quickly, and indefinately in varying temperatures, lack of uniformity of the deposit left upon the surface is sure to ensue. In fact, the author knows of hundreds of instances where a tar varnish applied to a tin roof would last four years, and be alligatored, and part of the same varnish taken from the same barrel and applied by the same painter the following day on an adjoining roof of the same conditions of surface would dry out and wash off within a year. Moreover, weather conditions and temperatures render the prevention of these defects of a highly volatile varnish impossible.

Rosin more readily impairs the stability of a coating into which it has entered than any of the other resins, and every ounce of it combined with a gallon of paint can be noticed to detract from its wearing qualities.

Many of the so-called paint dryers on the market are nothing more or less than a thin rosin varnish, and in consequence should be avoided. If, however, a dryer is absolutely needed, only oil dryers with thickening or oxygen absorbing properties should be used, and then only in minimum quantities, necessary to meet unavoidable requirements.

Chapter VI.

Diagnosing Conditions of Exposure.

This is an important matter in the selection of the most suitable paint for a purpose.

Plate II shows a smokestack below the roof in a sheet

Plate II.

mill. The paint was made by one of the most reputable manufacturers in the country, and was compounded of

high-grade raw materials. The manufacturer guaranteed it to last one year on this stack, which did not get over 700 degrees F. The condition of the paint, as shown in the illustration, became so one week after it was applied and thoroughly dry. Paint taken from the same mix in the barrel was applied on a tin roof in the neighborhood the same day, and five years afterward was in perfect condition, thus illustrating the proper use for that particular kind of paint. On the other hand, a cheaper and differently made paint was applied to this stack a few days later, after the scales were cleaned off, and it stood the exposure fairly well for one year, and on a tin roof in the neighborhood it did not preserve the metal over four months.

Samples, which are occasionally painted on small pieces of tin and sent out by the manufacturers to bend and twist, appear all right until they have been exposed to the weather for a year or so at which time their beautiful appearance and preserving qualities have quite vanished.

In order to select a protective coating to the best possible advantage the conditions of exposure should be thoroughly understood first; other conditions, such as the character of the surface, and number of coats to apply should follow.

The exposure of dry paint surfaces may be conveniently divided into eight classes as follows:

1. Ordinary interior exposures.
2. Ordinary exterior exposures.
3. Extraordinary interior exposures.
4. Extraordinary exterior exposures.
5. Extraordinary exposure to heat (other than atmospheric).
6. Extraordinary exposure to cold (other than atmospheric).
7. Extraordinary exposure to liquids (other than atmospheric).
8. Extraordinary exposure to abrasion (other than atmospheric).

No. 1. Ordinary interior exposure rarely covers a variation of temperature of more than 60 degrees F., consequently the expansion and contraction of the surface met with in this class of exposure is so small that it has very little effect upon an ordinary paint properly put on and of good materials, neither does moisture and its rapid

evaporation prevail, so that here we have a condition notable for its simplicity. Take, for instance, several small sheets of tin or iron with clean, bright, dry surface, coat them with coal tar varnish, asphaltum varnish, or, in fact, any cheap paint, and when thoroughly dry lay them aside in the drawer of a writing desk; 20 years later they will be in as good condition as the day they were stored away. The sheets of metal, even without paint, laid away, in like manner for the same length of time, will also be found to be in excellent condition. Structural iron work imbedded in cement or concrete or otherwise incased should have one coat of paint applied at the shop and two coats afterward, for the reason that subsequent coats cannot be applied after the building is completed, and once painted it is expected to remain so as long as the building lasts. Cement and concrete, moreover, are more or less porous and draw dampness to the metal.

No. 2. Ordinary exterior exposure meets with climatic conditions varying over 125 degrees F., ranging from the chilly blasts of cold weather to the scorching rays of the sun. Here expansion and contraction holds full sway, tugging and straining at the adhesive and elastic properties of the paint while adhering to a surface not succeptible to paint absorption.

Hail, snow and ice, thawing and freezing, rain and its evaporation attack vigorously the organic properties of the vehicle in a paint. When a varnish is used to withstand this class of exposure the heat from the sun continues to liberate what volatile matter it contains until it becomes baked so hard and brittle that its adhesiveness subsequently becomes a matter of only " here and there." If the varnish is a thick coating it is sure to become alligatored when the metal expands and contracts while in the hard condition, and if it is a thin coating it will become reduced to powder and wash off. This sort of exposure requires a paint of superior, elastic, adhesive, oxygen and water resisting properties, and as the top coat is the one subject the most of all to these conditions it should of necessity be made of carefully treated linseed oil, graphite and a suitable soluble solid composition to protect the oil so as to add permanence to the vehicle as explained. The reason for using graphite for the pigment is explained on page 22.

The class of steel work generally coming under this

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class of exposure is bridges, ornamental ironwork, fences, fire escapes, gutters, valleys, spouting, roofing, siding, towers, sheathing and shutters, &c. New materials of this class should receive at least one coat of paint at the works and one coat after it is put up.

No. 3. Extraordinary interior exposure, such as will be met in damp cellars, livery stable roofs (exposed on the under side to ammonia fumes), cast house roofs at furnace and foundries subjected to steam and heat, under side of roofs of steel mills directly over sulphuric acid, pickling vats, pulp mills, paper mills and ships' holds which sweat continuously, &c., have considerable effect upon the paint on the surface and paint thus exposed should dry harder and have more soluble solid in its composition than class No. 2: two good coats of the most suitable paint for this class of work are in most cases most satisfactory, and when the top coat loses its efficiency it should be replaced with another one before access to the metal is gained, as this will save considerable labor in removing rust which would otherwise form.

No. 4. Extraordinary exterior exposure are those exposures where the atmosphere is surcharged with acid fumes, which generally emanate from open coke ovens, chimneys, locomotive stacks and chemical works, &c. The effects of this class of exposure varies extensively. a great deal depending on the distance from where the fumes emanate and the character of them. Painted metal work of all kinds, especially roofs and bridges. in the vicinity of these quickly lose their protective coating if the paint is not made of the proper materials to withstand the exposure. Like class No. 2, this exposure necessitates the use of a protective coating capable of withstanding considerable expansion and contraction, and should not harden so much as the paint needed for class No. 3. It must furthermore have a vehicle protected by a soluble solid composition properly prepared to stand the surcharged atmosphere; and an inert pigment, such as graphite, white lead and red lead pigments, especially are to be avoided in this class. If this form of exposure is very severe three coats of paint should be used on the metal work.

No. 5. Extraordinary exposure to heat takes in those conditions where heat is produced by artificial means greater than atmospheric heat, and comes into direct contact with the painted surface. This heat may come

in contact with paint exposed to outside atmospheres, or it may come in contact with paint exposed to inside atmospheres. The class of materials subject to the former consists of smokestacks, blast furnace stoves and locomotive front ends, &c., and those subject to the latter consists of boiler fronts, furnace fronts and hot air and steam pipes. In all cases coming under this class the maximum amount of temperature should be ascertained,
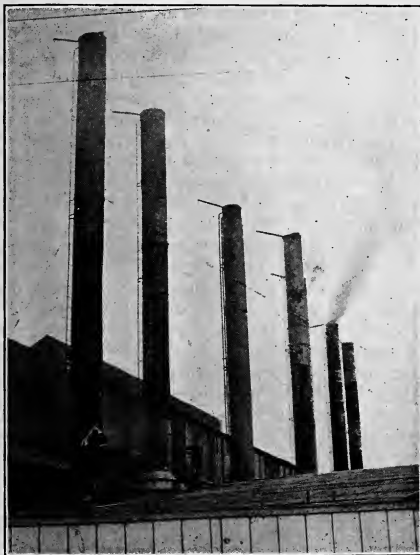

Plate III.

and if found to be more than the boiling point of water (212 degrees F.) a compound vehicle will be necessary. As explained on page 21, ordinary pigments, such as graphite, venetian red, yellow ochre, or umber, are practically fireproof, consequently the fact remains that the heat resisting properties of a paint is equal to the amount of heat which the vehicle will stand. Should the heat run

over 600 degrees F. little or no linseed oil should be used, and a soluble solid composition of a melting point a few degrees higher than the hot surface must necessarily be expected to be used for any permanence in this respect.

In 1902 officials of The American Sheet Steel Company called upon the author to make several tests personally on the hot smoke stacks over their pair furnaces and slab mills, stating that the paint when selected and bought would have to be applied to the stacks while hot. for the reason that the furnaces were always going and the fires could not be put out without too much expense and inconvenience.

Twenty-two different kinds of paints were tested in this manner, no two showing similar results. The author rather than allow anyone else to prepare the surface for the test and not do it thoroughly, did so himself, so that the experience thus gained would be of subsequent value. Plate III shows the author scraping the hottest portion of the stack which was to be tested. This operation was followed by the painter.

Flames were bursting forth from the tops of the first, second, third and fifth stacks, and the roofs were so hot that the soles of the shoes were scorched, and those making the test were compelled to keep moving. Vapor can be seen coming from the wet paint on the second stack, and the paint brush had to be moved fast in order to keep the bristles from burning. The scraping tools became so hot from induction that they were handled with difficulty.

Plate IV shows the tools that were available for cleaning at the time, and Plate V shows rust scales and old paint scales (one-quarter the diameter) removed.

Red heat of steel or iron is over 900 degrees F. and the author knows of no vehicle that will stand this heat and be water proof and rust preventing at the same time.

Whitewash or calcimine, sometimes called water paints, and sodium silicate used as a vehicle, will stand much more than 900 degrees F., but paints made of these will not stand water or moisture, nor will they stick to the surface long after being thoroughly hardened. Only one coat of paint is recommended by the author for this class of work, for the reason that extremely hot surfaces usually burn off the paint prematurely, in which case frequent applications are necessary, and two coats would be a considerable expense in so doing. It would

be folly, however, to expect to keep paint in a good condition for more than a few months on a surface as hot as 900 degrees F. The nearest material approaching a protective coating to stand over 900 degrees F. would be a coating of porcelain enamel. This would take more heat than 2000 degrees F. to melt it on the surface, and for
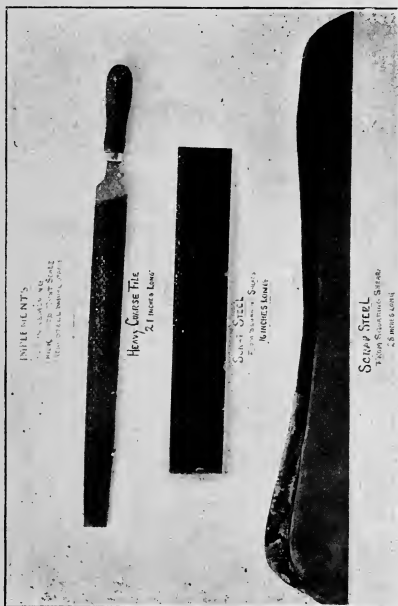

Plate IV.

this reason it would be an expensive and impractical operation, possible only on new work while in the factory preparatory to erection.

An approximate estimate of temperatures on a metal surface may be had by applying liquids of known boiling points on the surface and noting if they boil.

No. 6. Extraordinary exposure to cold generally takes

in conditions such as cold storage plants having steel construction within, the inside surface of steel plates composing ships bottoms, the outside surface of standpipes or water cylinders of hydraulic pumps, &c. The variations of temperature on these surfaces are slight or are below the amount necessary to injure a paint for the rea-
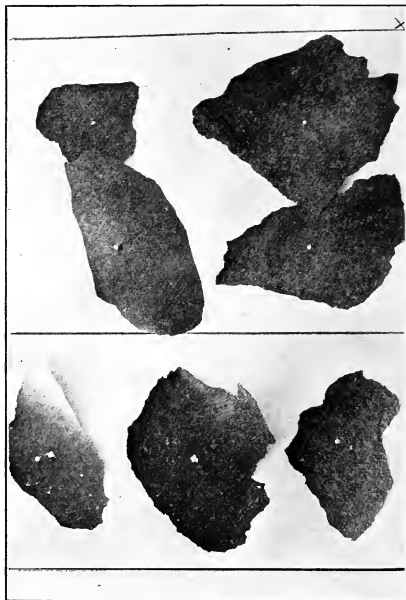

Plate V.

son that they rarely if ever reach higher than 70 degrees F. The greatest amount of injury which these conditions inflict to a paint is due to chilled vapor resulting from a damp atmosphere condensing on the surface resembling sweat. Should the conditions be such that this sweat reappears soon after it has been removed, preventing the maintenance of a dry surface long enough to apply the

paint and enable it to become dry. the painting should be deferred until the proper condition can be met with and then paint that will dry and harden quickly should be used. This will necessitate the use of a paint which has very little or no oxidizing oil.

A volatile solvent varnish vehicle paint containing graphite for a pigment and a soluble solid known to the author as Nicaragua gum, has been found to be the best for this class of work. This kind of paint hardens so thoroughly and so quickly that it would not stand such exposures as class No. 2 with any degree of certainty or satisfaction, and therefore should only be used for exposures of this class.

No. 7. Extraordinary exposures to liquids takes in a class where water is maintained in direct contact with the paint, such as ships bottoms, steel intake cribs, tanks, standpipes and portions of gas storage tanks commonly called gas holders. These require a compound vehicle paint with very little oil, or a varnish paint similar to that used for class No. 6, but should be heavier bodied and contain less volatile solvent, so that a heavy coating of the basic material will remain on the surface. This is necessary to withstand the extreme aqueous pressure against the paint film.

No. 8. Extraordinary exposure to abrasion takes in a class where friction eliminates a paint from a surface before it gets a chance to demonstrate its preserving properties by virtue of exposure to atmosphere, heat, gases or water, such as coal bunkers, ships' holds, freight cars and metallic shields underneath the flooring of bridges under which locomotives pass emitting carbonaceous grit from the smokestacks.

This class of paint should be slightly harder than that used for exposure No. 2, but not hard enough to become cracked or broken by violent blows, such as that of coal being loaded into cars and striking the surface of the car. It should have graphite exclusively for a pigment. This paint when almost dry should be dusted with the best quality of slippery dry graphite, then allowed to dry and then polished with a woolen swab or sheep skins with the wool on (using the wooly side). The finished surface will then have a highly glazed surface that will withstand more mechanical abrasion than any other form of paint coating which the author knows of.

Chapter VII.

The Selection of the Most Suitable Preservative.

The selection of the most suitable material should be governed not only by the class of exposure to be met

Plate VI.

with, but also the number of coats of paint to be used and the time allowed for it to dry properly.

Plate VI shows two samples selected from several

hundred of which the author has been giving thorough time tests. These samples were exposed in the Pittsburgh District, where the atmosphere is surcharged with sulphuretted hydrogen, carbon dioxide and sulphur fumes, &c. The paint was applied on bright, smooth sheets of
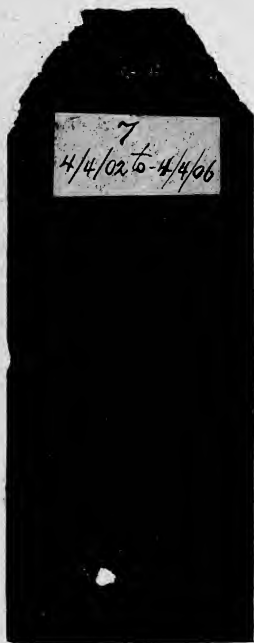

7
4/4/02 to 4/4/06

Plate VII.

steel. No. IV shows an improperly prepared graphite paint and No. VII shows a properly prepared graphite paint.

One shows that before the end of four years the protective qualities of the paint were exhausted and the steel to be badly eaten with rust. The other shows that

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the protective qualities of the paint were not impaired during the same length of time, the metal remaining as bright underneath the coating of paint as the day it was applied.

No. IV was taken from the regular stock paint of " a get rich quick " paint concern and was advertised as " their best grade " and the " best paint in the world."

No. VII was manufactured by a concern who does not make bombastic claims for their products, but depend upon their reputation for their continuance in business.

An enormous spreading capacity of a paint is often a misleading, fradulent or deceptive proposition offered to purchasers of paint in order to secure their patronage. The spreading capacity of almost any paint of good body may be increased by thinning it considerably with a volatile or a drying oil, and this decreases the cost per gallon by reason of the increased bulk resulting from its extension by the use of a cheaper thinning material than the cost of the paint. Therefore claims for supe- riority of a paint due to its superior spreading capacity should not necessarily add anything to the value to a statement of this sort. Furthermore, the less spreading capacity a paint has the more body it possesses. This body is generally the most costly part of a paint, and the fact that it is too heavy or thick to possess spreading qualities equal to a thinner paint should not detract from its value after taking into consideration the cost of the thinners necessary to reduce the body and increase the quantity and spreading capacity to the extent most de- sired.

A basis whereby deductions may be made to approxi- mate the average thickness of a coat of paint on a smooth flat surface, which does not absorb any of the paint, may be readily calculated in the following manner :

A legal standard United States gallon we know must contain 231 cu. in., and if 1 gal. of paint is spread over a surface containing 231 sq. ft., the wet paint will average 1-144 in. thick.

In like manner should the paint be spread twice as far and cover 462 square feet to the gallon it would be 1-288 in. which thickness can be compared to the thick- ness of the leaves of a book having 288 pages to the inch. Now when the paint is dry it will either thicken or be- come thinner—the former if a linseed oil paint and the

latter if a volatile oil varnish paint—therefore allowances should be made accordingly.

The writer believes that a protective coating averaging less than 1-144 in. thick is not sufficient protection to a metal surface exposed to any class of exposure intended for long service and that 1-72 in. is not necessary in any case where high grade material is used.

The spreading capacity of a paint should be averaged when based upon a standard condition of surface the

1 GALLON
OF PAINT

231 CUBIC INCHES

1 SQUARE FOOT
144 SQUARE INCHES

IS COVERED BY

1 CUBIC INCH
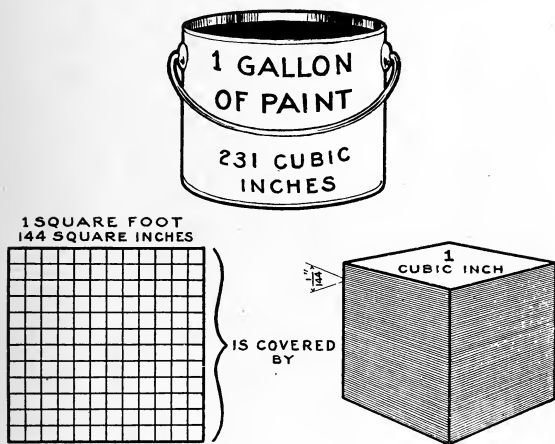
most suitable for the purpose being bright clean tin sheets or glass and estimates for other forms of surfaces based upon variations from the standard. The spreading capacity will also depend upon the temperature and for convenience 70 degrees F. is recommended.

Careful and slovenly spreading of paint will cause a great variation and lack uniformity of thickness of a coating, nevertheless in any case the attainment of an average estimate of thickness can not be depended upon. When, however, a paint is advertised to cover 1000 sq. ft. to the gallon it means necessarily that the coating must average less than 1-576 of an inch thick which may be compared to thin tissue paper.

Pigments may easily be tested for their fineness of texture by simply rubbing them in a dry state between the fingers or upon the palm of the hand, and if the pigment is mixed in a drying oil it can be separated out and dried by thinning the paint with gasoline, vigorously shaking together the mixture allowing the pigment to settle to the bottom, and washing out the heavy oil, then pouring off the liquid, repeating the operation until all of the drying oils have been extracted, after which the pigment may be dumped out upon a sheet of blotting paper and allowed to dry.

It will be noticed that the best grades of graphite " rub up " into a higher gloss between the fingers than any other known paint pigment and that when this pigment does not " rub up " into a slippery finish it is adulterated.

Vehicles may be tested in a simple way for commercial purposes by allowing the pigment to settle to the bottom, pouring the vehicle upon a piece of glass, allowing it to dry for 48 hours and then subjecting it to a temperature of say 200 degrees F. (up near a hot stove) for several hours, after which cool off by soaking it into cold water for 30 minutes, wipe dry with a cloth vigorously and see whether any of it will rub off, after which take the blade of a pocket knife and cut into it with a long steady cut beneath the paint and along the surface of the glass. If the vehicle can be then cut leaving long tough and elastic strips it can reasonably be expected to possess good qualifications for ordinary exposures met with. However for exposures such as 3, 4, 5, 6, 7 and 8 they should in addition be given actual time tests to the exact exposures to be met with, keeping detailed accounts of the conditions and the kind, quality and amount of raw materials used, so that the paints thus prepared for use may be intelligently compared for future selection.

Driers should be given the same test as the vehicle, noting, however, the strength of the drying properties, by the amount necessary for use with the vehicle and the time consumed in the drying of the oils thus tested.

A paint oil or varnish is considered by the author to be perfectly dry at such time when at a temperature of 70 degrees F. it refuses to adhere to a sheet of writing paper smoothed over it and pressed down hard by the palm of the hand. This condition at the very least

should prevail before additional coats of paint are applied.

However as much additional time as this condition requires to consume should be given before the same is attempted.

Volatile oils may be tested by allowing them to evaporate from a sheet of glass and noting whether there is a greasy deposit left on the surface, which if so, shows a substance which when entering into the liquid portion of a paint will seriously prevent the drying of it and cause an endless amount of annoyance, sometimes necessitating the removal of the paint entirely, which if not done would prevent the proper adhesion of more coats of paint.

A great deal more might be stated relative to the testing of materials.

The writer has noticed that the signs of the times show an increasing tendency unfortunately on the part of the general property owner to leave the question of maintenance and selection of materials to others. The luxurious modes of entertainment now prevalent entice the property-owner to more pleasant occupations during the intervals of the rush of business than formerly, when each property owner not only painted his own house but made his own paint and made it to last.

Chapter VIII.

Deductions and Conclusions.

After pursuing the subject of rust prevention it becomes very apparent that many questions are involved that do not clear the way, for those who cannot give it much thought or attention.

It does not take much of either, however, to deduce the following facts:

1. The property owner should be satisfied that the surface to be protected is as clean, dry, smooth and firm as it is possible to get it before his time, money or patience is expended thereon. Without this important condition any means to be employed would only be wasted. Inasmuch as the preparation of the surface, the employment of the proper kind of material and the quality of work done, when undertaken by a contractor may easily be manipulated by him in such a way that he may greatly profit financially to the detriment of the owner, it is recommended that the owner purchase his own material direct and hire his men by the day to do the work. Even should the men put in more time than necessary, the chances are that the work will not have been slighted, and that the total cost of the job would be much less than the same quality of work and materials would be supplied by the contractor.

2. The owner should purchase his paint in different shades, using a different shade for each coat, so that the detection of omissions in thoroughly covering the surface may be readily accomplished. The paint should be delivered on the ground in sealed packages guaranteed by the most responsible maker in whom the purchaser may have confidence.

3. It should be contained in receptacles that will maintain it in a good condition, and enable it to be thoroughly mixed or agitated during the progress of the work, so that the paint thus used is of a uniform consistency until the work in hand is fully completed.

Rain, dust, sand, mortar, plaster or refuse from buildings close by have often found its way into the paint barrel, rendering the contents unfit for use.

The great difference in the specific gravity between

pigment and vehicle causes the former to readily precipitate to the bottom in a very short time, even in the very best paints, and the best results can only be obtained by energetically keeping the paint stirred up.

The great drawback to the ordinary paint barrel is due to the fact that the head must be removed in order to thoroughly agitate the contents by means of a board or paddle.

To remove the head without destroying the barrel
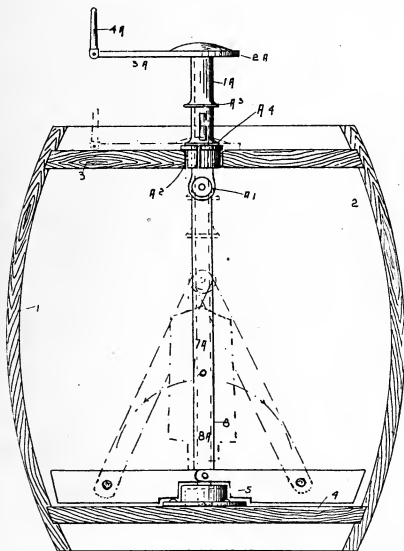
(which cost generally over $1.50 each) two or three hoops must be driven up to allow the staves to spread at the top, so that the head can be disengaged from the chime. When the staves spread in this manner openings are left between them, allowing the paint to run out, entailing waste and loss of time tightening up the barrel again.

Barrels containing various kinds of paint mixers have frequently been tried, but almost always have

proven either complete failures, or so unreliable that dependence upon them results invariable in the abandonment of their use. .

An ordinary barrel filled with good paint contains several hundred pounds of pigment, which when settled to the bottom becomes tough like putty.

The barrel paint mixers that have been tried becomes imbedded in the pigment and stuck fast with as much resistance apparently as would be experienced trying to turn a spade around when it is shoved down deeply in firm soil.

These drawbacks have led the writer into experiments resulting in the construction of a barrel paint mixer which is recommended to do the work.

The stem and crank as seen in the above illustration (1A, 2A, 3A) is made of a one-piece malleable casting, and the side arms or paddles are made of stiff spring steel ⅛ in. thick. These side arms are connected by means of loosely fitting rivets, and may be drawn up edgewise through the pigment so as to fold up, thereby reducing the diameter of the agitating surface, so that a portion of the pigment may be moved and mixed with the vehicle; after this is done the agitator paddles may be spread out as required until the whole width may be used for all of the pigment at one operation.

The mixer should be turned rapidly to the right for 8 or 10 revolutions, and then reversed quickly, this generates an undercurrent coming from the top in the form of a whirlpool, and leaves nothing to be desired in the matter of thorough agitation.

It is an important fact that the first coat of paint usually applied by the manufacturers on newly made metal work is of the cheapest variety, unless specifications and contracts to the contrary offset this result.

Every owner of property containing metal work that needs protection should thoroughly understand " what he needs as a preservative, and demand that it be properly applied by the painter."

Paint should be spread on a surface in temperatures between 50 and 90 degrees F., and should be spread on carefully that all air bubbles under the paint should be eliminated.

The application of paint with a machine or spray should not be encouraged, for the reason that air bubbles get under the fine spray and prevent the close ad-

herence of the paint to the surface, and also has a tendency to aerate the paint. The first coat on metal should not be quite as elastic as the succeeding coats. It should dry hard, tough and slightly yielding. Its subsequent hardening is somewhat prevented by the coat on top of it.

The last coat, or top coat, should dry slower than the one underneath, so as to withstand the drying tendency of the weather and meet expansion and contraction where it is mostly needed.

Black paints are the most opaque and should be used, not only because the material out of which they can be made affords the production of the best protective coating, but also for the reason that it presents a striking contrast to the color of rust or corrosion.

When red or brown paints are used the appearance of rust can only be detected at times when close inspection is promoted, and this is very often deferred by oversight or neglect.

Too much importance cannot be attached to the necessity of preserving metal before corrosion or oxidation has taken place.

The loss that generally ensues when metal surfaces are not continually protected in every corner and crevice is rarely appreciated. The wasted metal resulting from one moment's chemical action can never be replaced to its former condition (commercially speaking), and the section so effected is ofttimes so very difficult and costly to replace, especially in hidden structural work and bridges, that these matters are in many cases postponed until the whole structure becomes condemned as dangerous and a new one needs to be built.

Care should be employed by the purchaser of new structural work, bridges or sheet metal work, where the protective coating is furnished by the contractor; in seeing to the explicit and proper wording of the specifications so that the right brand, make and best paint materials are clearly defined so as to leave no valid chance for substitution. This rule should always govern wherever and whenever good paint is wanted. Specifications for applying the paint should always state " the number of coats wanted and that there should be no air holes, moisture, oil, grease or dirt under the paint; that it should be well brushed on by hand to a thoroughly cleaned and dry surface, thoroughly cover the said surface and be applied in dry weather between temperatures

of 50 to 90 degrees F. (unless the paint is a special kind and is shown by the purchaser to especially require different temperature for application ").
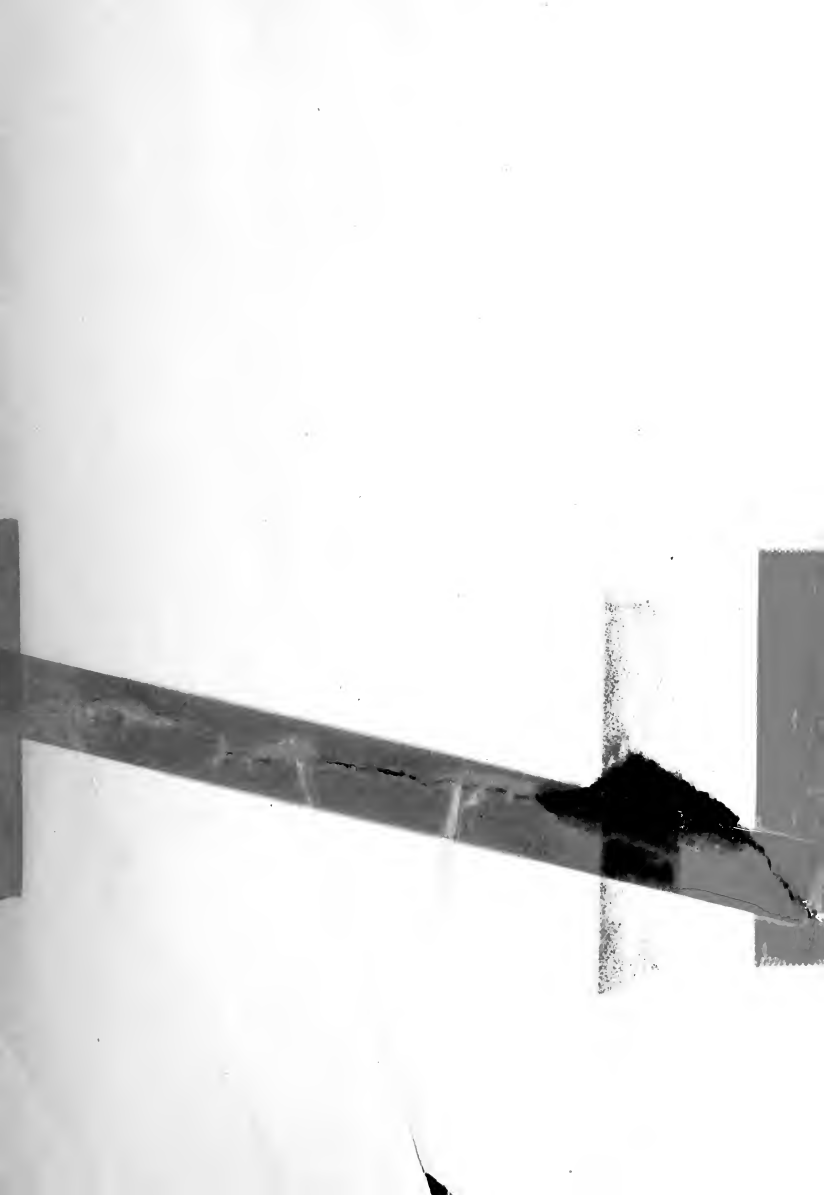
This should never be left for engineers to do, for a wide diversity of opinion exists as to what make or brand should be used, even among those of many years' experience.

Furthermore, engineers or architects very often refuse to specify any particular make of paint, for obvious reasons. It savors of partiality and leaves room for severe criticism. On the other hand, if the contractor can evade supplying an established brand of high grade material and suit himself in the furnishing of paint made of raw materials selected by himself, rendering it impossible for the engineer (without giving the material a daily chemical analysis), to ascertain its true value he has the chance to utilize the greater of the two evils to his own profit.

In cases where the engineer will not consult with the owner on the brand or make of paint to be used and specify the same in the contracts, the author suggests that the specifications read as follows: " All paint and paint materials used must be selected or approved by the owners before the same is permitted to be used. It shall be subject to the inspection and refusal of the engineer when the same is not branded or recognized as such." This would relieve the engineer of a responsibility which is not necessary for him to be expected to shoulder.

No engineer, in designing a structure, can make efficient allowance for decay, for the reason that the time, place and extent of such action is an unknown quantity and always will be.

Loss of life and property due to collapse resulting from decay is a serious theme to reflect upon. Any existing doubt as to the necessity of giving the work a good coat of good paint should be decided upon before it is too late.

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Loss
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